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Do morphometric measurements allow sex discrimination in Mockingbirds (*Mimus* sp)?

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Abstract:

Sexual dimorphism in birds may be expressed as differences in body size, plumage, color and/or behavior. Many species are monomorphic in color, making sex determination difficult in the field. An example of the latter are mockingbirds, which are passerines of the genus *Mimus*, endemic to the Americas. In order to distinguish between male and female mockingbirds using external body measurements that are easy to take, the objective of this work was to quantify morphometric differences between sexes in adults of the following species: *M. thenca* (45 specimens), *M. patagonicus* (95), *M. saturninus* (88), *M. triurus* (152), and *M. dorsalis* (7). We measured the following variables: culmen length, bill height and width, tarsus length, middle toe length, wing chord and tail length. Measurements were generally larger in males than in females except for bill width in *M. saturninus* and *M. triurus*, culmen length in *M. thenca* and *M. dorsalis*, and bill height in *M. dorsalis*. There were significant differences between sexes in wing chord for *M. patagonicus*, *M. saturninus* and *M. triurus*; tail length for *M. patagonicus* and *M. triurus*; tarsus length for *M. patagonicus*; and in middle toe length for *M. triurus*. No significant differences in measurements were found between sexes for *M. thenca*. Significant discriminant functions were obtained for *M. patagonicus*, *M. saturninus* and *M. triurus*, with a percentage of correct classification less than 80%. Only a few variables were useful for sex determination in the studied *Mimus* species, i.e. wing chord, tail length, middle toe length and tarsus length for three, two, one and one species, respectively.

Keywords: Mimidae; mockingbirds; morphometrics; sexual dimorphism; southern South America.

Introduction

Sex identification in animals is relevant for the understanding of many behavioral and ecological aspects[1], and is particularly useful for management and conservation[2]. In many bird species, sex identification can be achieved by direct observation of differences in plumage, structural traits such as colored soft-tissue, behavior, or by morphometric characters[3]. In passerines, sex might be determined by the presence/absence (female/male, respectively) of an incubation patch[4]. The external morphology cannot be used for sexing birds of monomorphic species, and differences in behavior between sexes are often restricted to the breeding season[5]. In these cases, the sex of birds can be determined by laparotomy[6, 7, 8] or molecular genetic analysis of blood or feather samples[9, 10, 11]. As an alternative to avoid destructive or invasive techniques, the use of external morphometrics to sex birds is of great value, being inexpensive and immediate in sex determination[12, 13]. In particular, external measurements are used in discriminant function analysis (DFA)[14] to distinguish the sex of numerous taxa in the field[16, 17, 18, 19, 20, 15]. In birds, the DFA has been effectively applied to a broad taxonomic range of species including: penguins[21, 22], divers[23], petrels[24, 25], cormorants[26, 27], vultures[28], gulls[29], skuas[30, 31], moorhens[32], rooks[33], flamingos[34, 11, 12], owls[35] and passerines[36].

Although external morphometric indices have been widely used in sexing birds, data of Passeriformes from the Neotropical region are scarce and fragmented[37, 38, 39, 40, 41, 42, 36].

Bird species that are sexually monomorphic for plumage but dimorphic for size may have differences in wings, tarsi or body mass[43, 36, 44]. According to Gill[45], sexual differences in size among birds may have resulted from the evolution of small females. In turn, these would have been favored by sexual selection, as they can accumulate more energy reserves required for egg formation and early breeding. However, females of some species are larger than males[46]; a situation known as reversed sexual dimorphism (RSD)[47]. This is common in raptorial birds such as hawks and owls of the orders Falconiformes and Strigiformes, respectively, and in the families Stercorariidae and Fregatidae[45].

The family Mimidae comprises 34 species of oscine songbirds, which are broadly distributed throughout the Americas, from southern Canada to the southern extreme of South America. These species mainly occupy scrublands and arid areas[48]. Southwestern North America is the center of diversity and radiation of the family, from where it expanded its range to islands of the Pacific and the Atlantic Oceans[49]. In temperate and subtropical South America, the only genus of the family is *Mimus* (Mockingbirds), with 6 species[48]. Three *Mimus* species, distributed from central to northern Argentina, have partly overlapping ranges but different habitats. In central Argentina, the White-banded Mockingbird (*M. triurus*) lives in sympatry with the Patagonian Mockingbird (*M. patagonicus*), but while the former is typical of low Chaco woodland and Monte scrub areas, the latter prefers arid lower desert scrub and steppe. Moreover, in the northeast region of Argentina the White-banded Mockingbird is extensively sympatric with the Chalk-browed Mockingbird (*M. saturninus*), which is typical of a more open, savanna-like country. The Brown-backed Mockingbird (*M. dorsalis*) occurs east of the Andes in arid foothill scrub similar to that occupied by the Patagonian and White-banded Mockingbirds. However, they are not in contact because *M. dorsalis* has a more northerly range from Bolivia south to the province of Tucumán, in northwest Argentina[49]. These four species together with the Chilean Mockingbird (*M. thenca*) form a monophyletic group[50].

These birds are territorial and sexually monomorphic in plumage[51, 52, 53, 49]. Some passerine species are known to be sexually monomorphic in plumage but dimorphic in size, with males usually larger than females[44]. In this regard, Deloach[54] suggested that the larger size of males of the Northern Mockingbird *Mimus polyglottos* is the result of evolutionary forces acting on male-male interactions or on female choice of mates.

In this study, we provide external morphometric data of five *Mimus* species. In four of these species we analyzed the differences in measurements between sexes to obtain discriminant functions that best distinguish the sexes.

Materials and Methods

Measurements were made on adult males and females of five Mimus species from the following museum collections: Museo de La Plata (La Plata), Fundación Miguel Lillo (Tucumán), Museo Argentino de Ciencias Naturales (Buenos Aires) and Museo Nacional de Historia Natural (Montevideo). We studied the following species: Chilean Mockingbird (23 males and 22 females), Patagonian Mockingbird (54 males and 41 females), Chalk-Browed Mockingbird (41 males and 47 females), White-banded Mockingbird (70 males and 82 females), and Brown-backed Mockingbird (2 males and 5 females).

We took seven external measurements following Baldwin *et al.*[55] and considering the recommendations of Winker[56]:

length of exposed culmen (Cu) from the anterior end of the nostril to the tip of the bill; bill height (BH) and bill width (BW) at the base of the bill; tarsus length (Ts) from the notch on the back of the intertarsal joint to the ventral surface of the foot with toes extended; middle toe length (MT); wing chord (WC) from the distal portion of the carpus to the tip of the longest primary feather; and tail length (Ta) from the base of the tail to the tip of the longest rectrix. The first five measurements were made using a caliper accurate to 0.01 mm and the last two with a metal ruler to the nearest 1 mm. To avoid bias all measurements were taken by the same person (D.M.). In addition, all measurements were made on the right side of each bird because some species show bilateral asymmetry (one side of the body is larger than the other)[57]. We recorded the sex and age of each specimen from the museum tag. Since specimens were prepared to enter the ornithological collections, sex determination was made at the time of this procedure, through direct anatomical examination.

The dimorphism index (DI[58]) was calculated for all the variables. The following formula was used:

$$DI = (A/B)*100$$

where:

A = mean value of variable "a" in females – mean value of variable "a" in males.

B = (mean value of variable "a" in males/2) + (mean value of variable "a" in females/2)

All variables were measured in millimeters. A positive index value indicates that the female is larger than the male and a negative value indicates the opposite.

In addition, we used the Student's t-test to evaluate differences in body measurements between males and females[59] in four species (*M. dorsalis* was excluded from the analysis due to the small sample size). Normality and homoscedasticity were tested using the Shapiro-Wilk's test and Levene's test, respectively[14, 59].

Discriminant Function Analysis (DFA) was used to develop the classification functions for sex assessment in mockingbirds[60]. *M. dorsalis* was excluded as described above. Discriminant functions were performed with all possible combinations of all measured variables. We also evaluated the performance of each single-variable as discriminant (univariate discriminant analysis). Forward discriminant analyses were applied to obtain combinations of characteristics (discriminant functions) that best distinguished the sexes. The associated cutting point value was calculated following Phillips and Furness[61]. The effectiveness of the discriminant analyses was checked in terms of the proportion of birds that were classified correctly and by a Jackknifed validation[62, 63, 61].

Results

The Student's t-test indicated that the measurements of male mockingbirds were, in general, larger than those of females (Table 1), except for the following variables: bill width for *M. saturninus* and *M. triurus*, culmen length for *M. thenca* and *M. dorsalis*, and bill height for *M. dorsalis*.

TABLE 1. Morphometric results of the five species of Mockingbirds (*Mimus* spp.) presented as mean ± standard deviation (SD) and range. Significant differences between sexes (Student's t-test) are indicated in bold. NS: $P>0.05$, *: $P<0.05$, **: $P<0.01$.

Species	Morphometric characters	Males			Females				
		Mean ± SD	Range	N	Mean ± SD	Range	N	*T*	*P*
M. thenca	Culmen Length	17.78±0.86	16.66-19.30	21	17.82±0.84	16.55-20.22	22	0.13	NS
	Bill Height	6.20±0.34	5.34-6.70	22	6.17±0.36	5.68-7.21	22	-0.24	NS
	Bill Width	5.87±0.54	4.82-6.6	22	5.84±0.40	5.12-6.75	22	-0.22	NS
	Tarsus Length	38.73±1.03	36.98-41.71	22	38.13±1.67	34.88-41.30	21	-1.39	NS
	Middle Toe Length	23.35±1.14	21.82-25.46	11	22.88±0.85	21.76-23.91	10	-0.86	NS
	Wing Chord	118.13±5.44	110.00-129.00	23	117.14±4.71	110.00-127.00	22	0.03	NS
	Tail Length	122.87±7.40	111.00-138.00	23	120.41±7.38	100.00-134.00	22	-1.12	NS
M. patagonicus	Culmen Length	16.56±1.24	14.30-20.25	52	16.19±1.47	13.70-20.00	39	-1.29	NS
	Bill Height	5.86±0.46	5.20-7.30	52	5.69±0.42	5.10-6.80	39	-1.77	NS
	Bill Width	5.59±0.38	4.80-6.50	54	5.48±0.34	4.80-6.30	40	-1.41	NS
	Tarsus Length	**35.61±1.70**	**29.10-38.00**	**54**	**34.60±1.54**	**31.30-38.80**	**40**	**-2.94**	**
	Middle Toe Length	19.62±1.05	18.24-22.50	31	18.99±1.59	13.70-21.80	26	-1.40	NS
	Wing Chord	**109.59±4.61**	**99.00-121.00**	**54**	**104.58±4.14**	**97.00-112.00**	**41**	**-5.47**	**
	Tail Length	**106.43±6.22**	**92.00-121.00**	**54**	**100.12±5.85**	**90.00-110.00**	**40**	**-4.98**	**
M. saturninus	Culmen Length	18.25±1.48	15.40-21.40	37	18.17±1.55	15.50-23.00	41	-0.21	NS
	Bill Height	6.69±0.41	5.82-7.50	37	6.62±0.50	5.50-7.90	43	-0.66	NS
	Bill Width	6.16±0.57	5.50-7.95	39	6.28±0.43	5.22-7.30	44	1.60	NS
	Tarsus Length	36.81±1.97	33.21-41.20	39	36.57±2.23	32.62-41.50	47	-0.53	NS
	Middle Toe Length	21.55±2.28	17.10-26.80	13	20.12±2.12	16.30-24.60	20	-1.83	NS
	Wing Chord	**119.28±4.68**	**110.00-130.00**	**40**	**115.17±5.28**	**104.00-125.00**	**46**	**-3.79**	**
	Tail Length	120.71±5.85	109.00-135.10	34	117.74±7.90	85.00-133.00	39	-1.53	NS
M. triurus	Culmen Length	15.55±1.00	14.00-20.90	80	15.25±0.99	13.10-17.90	67	-1.51	NS
	Bill Height	5.97±0.33	5.10-6.70	75	5.90±0.32	5.00-6.70	65	-1.24	NS
	Bill Width	5.62±0.40	4.45-6.50	82	5.67±0.37	4.61-6.50	69	0.46	NS
	Tarsus Length	32.65±1.25	29.60-36.87	82	32.22±1.58	26.60-36.20	70	-1.81	NS
	Middle Toe Length	**19.00±0.76**	**17.40-21.66**	**60**	**18.66±0.80**	**16.50-21.09**	**54**	**-2.33**	*
	Wing Chord	**107.08±3.72**	**99.00-117.00**	**81**	**102.98±4.00**	**94.00-115.00**	**70**	**-7.54**	**
	Tail Length	**110.11±5.60**	**85.00-129.00**	**77**	**104.98±5.02**	**93.00-115.00**	**66**	**-5.74**	**
M. dorsalis	Culmen Length	20.45±0.59	20.04-20.87	2	20.74±1.24	18.60-21.68	5		
	Bill Height	6.30±0.06	6.26-6.35	2	6.35±0.30	6.10-6.80	5		
	Bill Width	5.98±0.21	5.83-6.13	2	5.86±0.53	5.30-6.65	5		
	Tarsus Length	37.28±2.01	35.85-38.70	2	37.05±2.03	35.36-40.21	5		
	Middle Toe Length	20.22±0.51	19.86-20.58	2	19.23±1.05	18.14-20.30	5		
	Wing Chord	118.00±2.83	116.00-120.00	2	117.80±5.02	113.00-125.00	5		
	Tail Length	122.00±5.66	118.00-126.00	2	115.60±4.04	111.00-120.00	5		

These results were consistent with the negative values obtained from the analysis of the DI (Table 2).

TABLE 2. Dimorphism Index (DI) for body measurements of five species of Mockingbirds (*Mimus* spp.). The DI is positive if the female is larger and negative if the male is larger.

	Dimorphism Index						
Species	Culmen Length	Bill Height	Bill Width	Tarsus Length	Middle Toe Length	Wing Chord	Tail Length
M. thenca	0.22	-0.48	-0.51	-1.56	-2.03	-0.84	-2.02
M. patagonicus	-2.26	-2.94	-1.99	-2.88	-3.26	-4.68	-6.11
M. saturninus	-0.44	-1.05	1.93	-0.65	-6.86	-3.51	-2.49
M. triurus	-1.95	-1.18	0.89	-1.33	-1.81	-3.9	-4.77
M. dorsalis	1.41	0.79	-2.03	-0.62	-5.02	-0.17	-5.39

The comparison between males and females yielded significant differences in wing chord and tail length for *M. triurus* and *M. patagonicus*, in tarsus length for *M. patagonicus*, in wing chord for *M. saturninus*, and in middle toe length for *M. triurus* (Table 1). No significant differences in any of the studied variables were observed between sexes for *M. thenca*. The DI values of the five *Mimus* species studied ranged between -6.86 and 1.93, indicating low-to-moderate sexual dimorphism (Table 2).

Discriminant function analysis using all variables resulted in a significant discriminant function equation for *M. patagonicus* and *M. triurus*. The significant discriminant function for *M. patagonicus*, *M. saturninus* and *M. triurus* included the following predictors: culmen length, tarsus length and wing chord.

The DFA using the variables that had statistical significance with the Student's t-test resulted in a discriminant function for *M. patagonicus* (tarsus length, wing chord and tail length) and *M. triurus* (middle toe length, wing chord and tail length). In all cases, the percentage of correct classification was less than 80% (Table 3). The jackknifed validation provided the same classifications as those produced by the discriminant functions.

TABLE 3. Significant classification functions generated by Discriminant Function Analysis for 4 species of Mockingbirds, and percentage of correct classification. Cu: culmen length, BH: bill height, BW: bill width, Ts: tarsus length, MT: middle toe length, WC: wing chord, Ta: tail length. NS: $P>0.05$, *: $P<0.05$, **: $P<0.01$.

			Correct Classification %						
Species	Function	Cutting Point	Total	Male	Female	Wilks' λ	*F*	df_1, df_2	*P*
M. patagonicus	D1 = 0.302 Cu - 1.022 BH + 0.234 BW - 0.510 Ts + 0.131 MT - 0.056 WC - 0.066 Ta + 28.146	0.13	78.0	82.8	71.4	0.70	2.55	7, 42	*
	D2 = -0.101 Cu + 0.168 Ts + 0.204 WC -26.164	-0.08	75.6	82.7	65.8	0.74	9.54	3, 85	**
	D3 = - 0.101 Ts - 0.137 WC - 0.069 Ta + 25.497	0.97	76.3	85.2	64.1	0.73	10.69	3, 89	**
M. saturninus	D1 = - 0.325 Cu - 0.012 Ts + 0.229 WC - 20.570	0.006	67.6	64.7	70.0	0.81	5.61	3, 70	**
M. triurus	D1 = - 0.146 Cu - 0.711 BH + 0.722 BW + 0.273 Ts - 0.252 MT - 0.254 WC - 0.009 Ta + 25.68	1.04	75.0	72.5	77.8	0.61	7.49	7, 86	**
	D2 = 0.151 Cu - 0.040 Ts + 0.259 WC - 28.163	-21.64	76.7	79.7	73.1	0.72	17.84	3, 141	**
	D3 = - 0.116 MT - 0.231 WC - 0.024 Ta + 29.064	0.034	76.63	76.78	76.47	0.65	18.38	3, 103	**

Discussion

In this study, we investigated whether the sex of five mimid species can be determined by external morphological characters. Our results show that measurements were larger for male than female mockingbirds, except for bill width in *M. saturninus* and *M. triurus*, culmen length in *M. thenca* and *M. dorsalis*, and bill height in *M. dorsalis*.

Montalti *et al.*[36], who studied other sexually monochromatic Neotropical Passeriformes, found significant differences between sexes in wing chord for the Brown-and-Yellow Marshbird *Pseudoleistes virescens*; middle toe length for the Great Kiskadee *Pitangus sulphuratus*; tarsus length for the Freckle-breasted Thornbird *Phacellodomus striaticollis* and *P. virescens*; tail length for the Rufous-collared Sparrow *Zonotrichia capensis* and culmen length for *P. virescens*. Moreover, the culmen of Rufous Horneros *Furnarius rufus*, *P. sulphuratus*, and the Tropical Kingbird *Tyrannus melancholicus* was longer in females than in males.

In our study, the dimorphism indices for the five *Mimus* species revealed low-to-moderate sexual dimorphism in most of the analyzed variables.

We found sexual dimorphism in tarsus length, middle toe length, wing chord and tail length depending on the species, while *M. thenca* was sexually monomorphic for all the studied characters.

Deloach[54] found that males of *M. polyglottos* showed significantly higher differences in wing chord and weight as compared with females. This author suggested that differences between sexes may have resulted from selective pressure driven by male-male interactions in the context of territorial competition or by female choice of larger mates. Our results are similar to those found by Deloach[54], since we noted that males have larger wings than females in *M. patagonicus*, *M. saturninus*, and *M. triurus*.

Although the DFA produced significant discriminant functions separating males from females based on the morphometry of some mockingbird species, the percentages of correct classification were low thus indicating that the measurements used are not reliable enough for sexing these birds using this technique. However, we found significant differences in some measurements between sexes for three of the studied species.

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